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CAMERON BOLITHO BROWNE

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For: METHOD AND APPARATUS  
FOR TRANSFORMING A  
SET OF CLOSED CURVES

Examiner: Not Assigned

Group Art Unit: 2772

Date: November 10, 1999

Assistant Commissioner for Patents  
Washington, D.C. 20231

CLAIM TO PRIORITY

Sir:

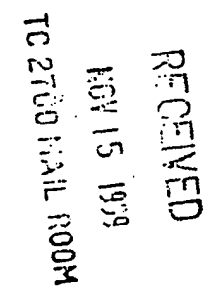
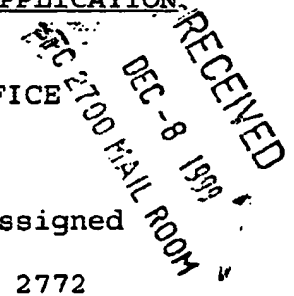
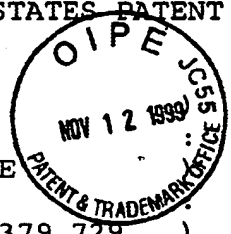
Applicant hereby claims priority under the  
International Convention and all rights to which he is  
entitled under 35 U.S.C. § 119 based upon the following  
Australian Priority Application:

<u>Application No.</u>	<u>Date Filed</u>
PP5577	August 28, 1998

A certified copy of the priority document is  
enclosed.

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Applicant's undersigned attorney may be reached in our New York office by telephone at (212) 218-2100. All correspondence should be directed to our new address given below.

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I, KIM MARSHALL, MANAGER EXAMINATION SUPPORT AND SALES, hereby  
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Application No. PP 5577 for a patent by CANON KABUSHIKI KAISHA filed on  
28 August 1998.

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**ORIGINAL**

**AUSTRALIA**

**Patents Act 1990**

**PROVISIONAL SPECIFICATION FOR THE INVENTION ENTITLED:**

Method and Apparatus for Transforming a Set of Closed Curves

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This invention is best described in the following statement:

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## METHOD AND APPARATUS FOR TRANSFORMING A SET OF CLOSED CURVES

### Field of Invention

5       The present invention relates to a method and apparatus for transforming a set of closed curves. The invention also relates to a computer program product including a computer readable medium having recorded thereon a computer program for transforming a set of closed curves.

### 10   Background of Invention

      In the fields of computational geometry and graphics, it is often desirable to modify the shape of an object in some consistent, reproducible and controllable manner, to produce a result that satisfies some criteria regarding shape or form. Such criteria might include the transformation of shapes to those that are considered to be more  
15   artistically appealing or complex, but still retain the basic shape of the original outline.

      For instance, it may be desirable to transform computer typeface or font defined by character shape outlines to produce more interesting and artistically pleasing results, where the basic overall outline shapes are maintained so that readability is not lost.

      The publication United States Patent No. 5,701,404 discloses a method for  
20   trimming non-uniform rational B-spline surfaces according to curves projected onto them. However, this method suffers from the disadvantage that the basic overall shape of the original outline is not retained.

### Summary of the Invention

25       It is an object of the present invention to ameliorate one or more disadvantages of the prior art.

      One or more exemplary aspects of the invention are listed below, but are not limited thereto.

According to one aspect of the invention there is provided a method for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the method including the steps of;

(i) providing a pattern including a set of continuous second curves for  
5 projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

(ii) determining a set of intersection points of the set of first curves with the set of second curves;

(iii) determining a set of crossover points within the set of intersection points;  
10 and

(iv) selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

According to another aspect of the invention there is provided an apparatus for  
15 transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

20 a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

a first selecting means for selecting curve intervals, delimited by the crossover  
25 points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

According to still another aspect of the invention there is provided a computer program product including a computer readable medium having recorded thereon a

computer program for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second  
5 curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

10 a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

#### 15 Brief Description of the Drawings

Embodiments of the invention are described with reference to the drawings, in which:

Figs. 1A to 1C illustrate the concept of a crossover point;

Figs. 2A to 2C further illustrate the concept of a crossover point;

20 Figs. 3A and 3B illustrate the definition of a crossover point, and a special case of crossover;

Fig. 4A illustrates an intersection point that is not a crossover point;

Figs. 4B and 4 C illustrate an example of the of forward and backward direction for a closed curve C;

25 Fig. 4D illustrates the concept of positive and negative direction for a open continuous curve;

Fig. 5 is a flow diagram of the preferred method for transforming a set of closed curves.

Fig. 6 is a flow diagram showing in more detail the step 510 of Fig. 5

Fig. 7A illustrates the set of closed curves C of character "A";

Fig. 7B illustrates the filled counterpart of Fig. 7A;

Fig. 8 illustrates an example pattern P composed of parallel sinusoidal curves;

Fig. 9A illustrates C' the result of intersecting C of Fig. 7A and P of Fig. 8;

5 Fig. 9B illustrates the filled counterpart of Fig. 9A;

Figs. 10A illustrates C' the inverted result of intersecting C of Fig. 7A and P of Fig. 8;

Fig. 10B illustrates the filled counterpart of Fig. 10A;

10 Figs. 11A and 11B illustrate the crossover points and curve intervals formed by the intersection of a closed curve set C and pattern P, and the resulting shape C';

Fig. 12 illustrates an example of null transformed curve set C' from a single pattern P curve intersected with C;

Fig. 13 illustrates an example of a transformed curve set C' from a single pattern P curve intersected with C;

15 Fig. 14 illustrates another example of a transformed curve set C' from a single pattern P curve intersected with C;

Figs. 15A and 15B illustrate the result of inverting a transformed curve set C';

Fig. 16 illustrates the order of processing for multiple C' regions;

20 Fig. 17 illustrates the order of processing for multiple C' regions in the presence of a hole;

Figs. 18A to 18C illustrate various transformations that can be achieved using different P base shapes;

Fig. 19 illustrates a transformation utilising a checkerboard effect ;

Fig. 20 illustrates a transformation utilising a gradient effect; and

25 Fig. 21 is a block diagram of a general purpose computer with which the embodiments can be implemented;

#### Detailed Description

#### Preferred Embodiment of Method(s)

Before proceeding with a description of the embodiments, a brief review of terminology used hereinafter is provided.

Figs. 1A to 1C illustrate the concept of the term "crossover point". In Fig. 1A, curves AB 100 and CD 102 do not contain any intersection or crossover points. In Fig. 1B, curves AB 104 and CD 106 intersect at point I 108 but do not crossover. In Fig. 1C, curves AB 110 and CD 112 have two intersection points J 114 and K 116, which are both hereby classed as being crossover points.

This concept is further illustrated in Figs. 2A to 2C, where an identical case is shown for differently shaped curves. In Fig. 2A, curves AB 200 and CD 202 contain no intersection or crossover points. In Fig. 2B, curves AB 204 and CD 206 contain one intersection point I 208 but no crossover points. In Fig. 2C, curves AB 210 and CD 212 contain two intersection points J 214 and K 216, which are both also crossover points.

Fig. 3A illustrates in more formal terms the definition of a "crossover point". Curves AB 300 and CD 302 intersect at point P 304. Examining point O 306 along AB immediately prior to the intersection point P, and point Q 308 along AB immediately following the intersection point P, it is observed that O and Q lie on opposite sides of curve CD, that is, curve AB has "crossed over" curve CD at point P. Similarly, it can be said that curve CD has "crossed over" curve AB. Intersection points exactly define crossover points, but not all intersection points are necessarily crossover points. The complete set of crossover points between a first set of curves C and a second set of curves P is referred to as a crossover set X. A closed curve which crosses over itself and thus intersects itself, is referred to as a self-crossover.

Fig. 3B illustrates a special case of curves EFGH 310 and IJ 312 that share a common interval between points F 314 and G 316. Points F and G and all points with in the interval FG are intersection points. However, there is only one crossover along this interval FG, so a single point from this interval must be chosen to represent the crossover point. To maintain consistency and ensure a reproducible result, the

convention used in the preferred embodiment is that the first point encountered along the shared interval is chosen as the crossover point, point F in this case.

Fig. 4A illustrates the case of an intersection point that is not a crossover point. Curves AB 400 and CD 402 intersect at point P 404. However, in this case it is  
5 observed that point O 406 along AB immediately prior to the intersection point P, and point Q 408 along AB immediately following the intersection point P, both lie on the same side of curve CD, that is, curves AB and CD have not crossed over.

Fig. 4B illustrates the concept of positive and negative direction for a open continuous curve. The open continuous curve AB is represented in a parametric form  
10  $x=f(t)$ ,  $y=g(t)$  having a parameter  $t$  commencing at  $t_0$  and terminating at  $t_n$ . The direction from  $t_0$  to  $t_n$  along the curve AB is defined as the positive direction where  $t_0 \leq t \leq t_n$ . The negative direction is defined as that direction along the open curve AB which is opposite to the positive direction. Of course, the actual direction of the positive direction of a curve AB is dependent upon the choice of parametric functions.

15 Figs. 4C and 4D illustrate an example of the forward and backward direction of a closed continuous curve C. The forward direction of a closed curve C which bounds an object R is defined herein as that direction along the closed curve C which has the object on a specified side. The backward direction of the closed curve C is defined herein as that direction along the closed curve C which has the object on the side  
20 opposite to the specified side. In the examples given herein, the specified side is the right hand side. In Fig. 4C, the object R bounded by the curve C is located inside the curve C. Thus the forward direction is along the curve C in the direction  $t_p$  to  $t_q$ . In Fig. 4D, the same curve C is shown. However, the object R bounded by the curve C is located outside the curve C. Thus, the forward direction in these circumstances is from  
25  $t_q$  to  $t_p$ . In these examples, it can be seen that the forward direction is in a clockwise direction where the closed curve C bounds the object R within its interior and that the forward direction is in the anti-clockwise direction where the closed curve C bounds the object R on its exterior. Alternatively, the specified side may be chosen as the left hand side. In this case, the forward directions of Figs. 4C and 4D are consequently

reversed. Whatever alternative is chosen, it should be used consistently throughout the preferred method to ensue reproducibility.

Now turning to Fig. 5, there is illustrated a flow diagram of the preferred method for transforming a set of closed first curves defined on a surface. The preferred method is described with reference to 2-dimensional examples, in particular the orientation of 2-dimensional curves that describe the paths of stroke-based typeface characters. However, the principles of this invention have general applicability to n-dimensional space curves and are not intended to be limited to 2-dimensional curves only.

In step 500 of the preferred method, the process commences and a set of closed first curves defined on a 2-dimensional planar surface is inputted. Alternatively, the set of closed first curves may be defined on a 3-dimensional surface, where a 3-dimensional effect is desired. Figs. 7A and 7B illustrate a typical example of a set of closed first curves. Specifically, Fig. 7A illustrates a character glyph of a font described by its outline path 700. Fig. 7B illustrates its filled counterpart that describes a region R 704 enclosed by the outline path 700. In Figs. 7A and 7B the outline path 700 describes a set of curves C, which are continuous closed curves that contain no self-crossovers. The set of curves may include holes in the outline shape 702, typically represented in industry standard typefaces by curves oriented in the opposite direction to exterior curves. The shape of C dictates the overall shape of the transformed result.

In step 502, a pattern including a set of second curves is generated in response to user input 504. Fig. 8 illustrates a typical example of a pattern including a set of second curves that lie on the same surface as C, and constitute such a pattern P 800. The constituent curves of P may be open-ended, but within the region R they are continuous and contain no self-crossovers or intersections between members of P. The pattern P may be a generated by an implicit function, and parameterized to describe characteristics such as base shape, period, amplitude, gradient, and so on. The pattern P need only be generated for the region R, increasing efficiency. Alternatively, the pattern P may be retrieved from storage means.

In the next step 506, the intersection points of the set of first curves C and the set of second curves P are determined. The intersection step can be performed efficiently through the use of standard computational methods such as local neighborhood search, or ordering curve segments by coordinate and performing scanline traversal. Fig. 11A illustrates the intersections of a set of closed first curves C and a set of pattern curves P. Specifically, Fig. 11A shows one closed curve C 1100 and a set of pattern curves P composed of curves P<sub>1</sub> 1102 and P<sub>2</sub> 1104. In the step 506, firstly all the intersection points X<sub>1</sub>, X<sub>2</sub>, X<sub>3</sub> and X<sub>4</sub> between C and P are determined.

In the next step 508, a set of crossover points X is determined from the set of intersection points. In this step 508, each intersection point is tested for crossover, resulting in the crossover point set X composed of X<sub>1</sub> 1106, X<sub>2</sub> 1108, X<sub>3</sub> 1110 and X<sub>4</sub> 1112. As the curve C is continuous, closed, and contains no self-crossovers, and as the curves P are continuous and contain no self-crossovers within the region R of the closed curve C, then the crossover point set X will always contain an even number of crossover points, as any crossover entering R must have a corresponding crossover leaving R.

In the next step 510, the transformed curve set C' 1122 shown in Fig. 11B is constructed by assembling closed loops of intervals along C and P delimited by crossover points X<sub>n</sub>. For instance, the transformed curve set C' 1122 is assembled from the following curve intervals:

- a) interval 1114 along C between X<sub>1</sub> and X<sub>2</sub>,
- b) interval 1116 along P between X<sub>2</sub> and X<sub>3</sub>,
- c) interval 1118 along C between X<sub>3</sub> and X<sub>4</sub>,
- d) interval 1120 along P between X<sub>4</sub> and X<sub>1</sub>.

Curve intervals are directed according to crossover point ordering, and adjacent intervals are joined at crossover points. The complete loop returns to the start point X<sub>1</sub>, reclosing the transformed curve. This example results in a transformed curve set C' 1122 with a single closed curve member, however multiple C' members may as



easily be obtained, and there is not necessarily any correspondence between the cardinality of C and the cardinality of C'.

In step 512, the transformed closed set of curves are displayed on a monitor and/or printed. Afterwards, the processing terminates at step 514.

5       Turning now to Fig. 6, there is shown the step 510 of Fig. 5 in more detail. In step 610, all the crossover points within the set of crossover points X are ordered in accordance with a predetermined order. The ordering of crossover points within X is independent of intersection point ordering. In the preferred embodiment, crossover points are ordered according to their position along C in a clockwise direction (note that  
10 each crossover member of X has a defined position along both P and C) to ensure consistency and reproducibility.

In step 611, the transformed curve set C' is set to empty and all the crossover points  $X_n$  are marked as "unvisited". In step 612, the set of crossover points is examined in order, and a new transformed curve is started at an "unvisited" crossover  
15 point  $X_1$ , that is highest in the order. This "unvisited" crossover is then marked as "visited".

In decision block 614, a check is made to determine whether or not the crossover point last marked as "visited" is the first crossover point  $X_1$  in the current closed loop. If decision block 614 returns false (No), then processing continues at step 622.  
20 Otherwise processing continues at step 616. In step 616, the first curve interval of the current loop selected, delimited by crossover points. This selection process 616 selects the curve interval along C that commences at the first crossover point  $X_1$  and that proceeds in the forward direction and terminates at the next adjacent unmarked crossover point  $X_2$ . In the next step 618, the terminating crossover point  $X_2$  is marked  
25 as "visited".

In the decision block 620, a check is made whether or not a closed loop has been formed. This is determined by checking whether the last mentioned terminating crossover point  $X_n$  is the same as the first crossover point  $X_1$ . If the decision block 620

returns true (Yes), then processing continues at step 625. Otherwise processing continues at decision block 614.

If decision block 614 returns false, namely when the last marked crossover point is not the first crossover point  $X_1$  in the closed loop, then processing continues at step 622. In step 622, the next curve interval in the current loop is selected delimited by crossover points. This selection process 622 selects the curve interval along C or P that commences at the last marked terminating crossover point and terminates at an unmarked adjacent crossover point. This selection process 622 can thus chose the next curve interval from the four curve intervals available. The selection process selects the first interval encountered around the last marked terminating crossover point in the anticlockwise direction. In the next step 624, the unmarked adjacent crossover point of the selected interval is marked as "visited" and the processing continues at decision block 620. If the decision block 620 determines a closed loop has been formed, then the processing continues at step 625. Otherwise the steps 614,622,624 and 620 continue until the transformed loop is formed. In step 625, the transformed closed curve is added to the transformed curve set  $C'$ .

Given that crossover points by definition result in intervals belonging to alternating curve sets (C, P, C, P and so on) around any crossover point  $X_n$ , then the first interval encountered around  $X_2$  in the anticlockwise direction must belong to P. Also, intervals along C will always be followed in the forward direction, however, intervals along P may be followed in either the positive or negative directions. During the first pass of step 622 the interval  $X_2X_3$  will be selected. The next interval selected by step 622 is interval  $X_3X_4$ . Arriving at  $X_4$ , the first interval in anticlockwise order belongs to P, and thus the next pass of step 622 selects interval  $X_4X_1$ . As the next crossover point  $X_n$  is  $X_1$ , the curve's starting point, a complete loop has been traversed and the curve is closed and added to the transformed curve set  $C'$ . Each terminating crossover point  $X_n$  is marked as "visited" once a curve interval has been selected and processed.

In the decision block 626, a check is made whether or not all closed loops have been formed. This is preferably determined by checking whether all the crossover points  $X_n$  are marked as "visited". If the decision block 626 returns true (Yes), then processing continues at step 512 and the transformed curve set  $C'$  is complete.

5 Otherwise the processing is returned to decision block 614.

The preferred method has the advantage that it is applicable to general surfaces, and assumes minimal dependency between the source and target curve sets, beyond their existing on the same surface. The transformation may be safely applied to arbitrary outline shapes provided that they have no self-crossovers.

10 Moreover, the transformation process is consistent, reproducible and controlled so that it can be applied to any outline shape, without the need for intervention by the user beyond the setting of certain parameters. The pattern curve set may be defined implicitly, and calculated on demand to fit the region occupied by the source curve set.

In addition, the transformed curve set is preferably alternating, in the sense that  
15 neighboring closed regions may touch at common points but do not overlap or intersect. Consequently, a regularly spaced pattern set will result in a set of regularly spaced closed curves alternating with regularly spaced vacant areas. This allows artistic effects such as striping, gradient and checkerboard to be applied to outline shapes.

## 20 Examples

The following examples are simply provided for illustrative purposes of the preferred method and other closed curve sets  $C$  and patterns  $P$  can be employed without departing from the scope and spirit of the invention.

Fig. 9A shows the result of the implementation of the preferred method on the  
25 text characters shown in Fig. 7A using the pattern shown in Fig. 8. Specifically, Fig. 9A shows the result of transforming the curve set  $C$  700 with the pattern  $P$  800, giving the transformed curve set  $C'$  900. The transformed curve set  $C'$  900 encloses a region  $R'$  902. In Fig. 9B, this region  $R'$  may be filled resulting in filled regions 904

which alternate with vacant areas 906. These filled regions do not overlap or intersect with other filled regions, but may share common points.

Shown in Figs. 10A and 10B are inverted transformed curve sets  $C_i'$  1000 created by transforming curve set C 700 with the pattern set P 800. The filled region  $R_i'$  enclosed by  $C_i'$  1000 is shown as 1004. It can be seen that filled regions 904 described by C' become vacant areas in  $C_i'$  1006, and that vacant areas 906 described by C' 900 become filled areas 1004 in  $C_i'$  1000. Again, filled regions 1004 do not overlap or intersect with each, but may share common points.

Turning now to Fig. 12, there is shown non-intersecting first curve sets C 1202 and P 1200 that result in the empty curve set C' following transformation. As there are no intersection points, there can be no crossover points, and therefore no new transformed curves are assembled.

Fig. 13 shows intersecting curve sets C 1300 and P 1302 that result in a transformed curve set C' with a single member 1304. This is similar to the result illustrated in Fig. 11A.

Turning now to Fig. 14, there is shown intersecting curve sets C 1400 and P 1402 that result in a transformed curve set C' with multiple members 1404 & 1406. Note that in all three cases shown in Figs. 12 to 14 the curve sets C and P are similar but are in different relationships to each other, giving markedly different transformation results.

In the example illustrated in Fig. 14, the crossover point  $X_1$  1408 is examined first, and the interval  $X_1X_2$  along C is traversed. At  $X_2$  1410 the interval  $X_2X_1$  along P is chosen, leading back to the starting point  $X_1$  and closing the transformed curve 1416 that is added to C'. At this stage  $X_1$  has been examined as a candidate for a new transformed curve, and  $X_1$  and  $X_2$  have been visited.  $X_2$  is examined next, but is ignored as it has already been visited.

The crossover point  $X_3$  1412 is next examined and is found to be unvisited. A new transformed curve is started at  $X_3$ , and the interval  $X_3X_4$  along C is traversed. At  $X_4$  1414 the interval  $X_4X_3$  along P is chosen, leading back to this transformed curve's

starting point and closing the transformed curve 1418 that is added to  $C'$ . At this stage  $X_1$ ,  $X_2$  and  $X_3$  have been examined as candidates for new transformed curves, and  $X_1$ ,  $X_2$ ,  $X_3$  and  $X_4$  have been visited.  $X_4$  is examined next, but is ignored as it has already been visited, and the transformed curve set  $C'$  is complete.

5        Figs. 15A and 15B demonstrate that the cardinality of  $C'$  and the cardinality of  $C_i'$  are not necessarily the same. The same curve set  $C$  1500 and pattern set  $P$  1502 is used in both cases, but  $C'$  yields a transformed curve set with two members curves 1504 and 1506, while the inverted transformed curve set  $C_i'$  has only one member 1508.

10        Fig. 16 illustrates the complete transformation process of curve set  $C$  1600 and pattern set  $P$  composed of curves  $P_1$  1602,  $P_2$  1604,  $P_3$  1606 and  $P_4$  1608 into the transformed curve set  $C'$  composed of two curves 1612 and 1610. Following the intersection of  $C$  with  $P$ , the following crossover point set  $X$  is obtained and ordered as follows in the forward direction around  $C$ :  $X_1$  1614,  $X_2$  1616,  $X_3$  1618,  $X_4$  1620,  $X_5$   
15    1622,  $X_6$  1624,  $X_7$  1626 and  $X_8$  1628. The transformed curves are assembled in the following order:

- a) interval  $X_1X_2$  1630,
- b) interval  $X_1X_7$  1632,
- c) interval  $X_7X_8$  1634,
- 20    d) interval  $X_8X_1$  1636,
- e) interval  $X_3X_4$  1638,
- f) interval  $X_4X_5$  1640,
- g) interval  $X_5X_6$  1642,
- h) interval  $X_6X_3$  1644,

25        Following which two new transformed curves 1610 and 1612 have been added to  $C'$  and all the crossover points  $X_n$  have been visited.

Fig. 17 illustrates the behaviour of the transformation process in the presence of holes. Curve set  $C$  consists of two distinct non-intersecting curves 1700 and 1702. The interior curve  $C_2$  1702 has a forward direction opposite to that of the exterior curve

$C_1$  1700 and defines a hole in region  $R$ . The pattern curve set  $P$  consists of three distinct non-intersecting curves  $P_1$  1704,  $P_2$  1706 and  $P_3$  1708.  $P_3$  is closed and totally contained within the region bounded by exterior curve  $C_1$ , but is valid as it is continuous within  $R$ , and does not intersect itself or any other member of  $P$ . In this example, the crossover points are ordered in a clockwise direction around  $C_1$  and in an anticlockwise direction around  $C_2$ , and thus form the ordered set  $X_1$  1710,  $X_2$  1712,  $X_3$  1714,  $X_4$  1714,  $X_5$  1716,  $X_6$  1718,  $X_7$  1720,  $X_8$  1722,  $X_9$  1724 and  $X_{10}$  1726. Starting at the first point  $X_1$  a new transformed curve  $C_1'$  1728 is created, and is assembled in the following order:

- 10           a) interval  $X_1X_2$  along  $C_1$ ,
- b) interval  $X_2X_3$  along  $P_2$ ,
- c) interval  $X_3X_4$  along  $C_1$ ,
- d) interval  $X_4X_5$  along  $P_2$ ,
- e) interval  $X_5X_6$  along  $C_1$ ,
- 15           f) interval  $X_6X_8$  along  $P_1$ ,
- g) interval  $X_8X_9$  along  $C_2$ ,
- h) interval  $X_9X_1$  along  $P_1$ .

The next unvisited point in the ordered set  $X$  is  $X_7$ , from which a new transformed curve  $C_2'$  1730 is assembled. In this case, the forward interval along  $C_2$   $X_7X_8$  leads to a visited point  $X_8$ , so the method backtracks to the  $C_2$  point immediately prior to  $X_7$ , which in this case is the crossover point  $X_{10}$ . The crossover point  $X_{10}$  is now treated as the starting point for  $C_2'$ , and the method proceeds as for the usual case.  $C_2'$  is assembled in the following order:

- a) interval  $X_{10}X_7$  along  $C_2$ ,
- 25           b) interval  $X_7X_{10}$  along  $P_3$ .

Following this all points  $X$  have been visited and the transformed curve set  $C'$  is complete.

By way of further example, Figs. 18A to 18C illustrate various transformations of the curve set  $C$  1800 with pattern sets composed of different base shapes. The

transformed curve set C' 1802 shows the transformation resulting from a pattern set derived from a triangular wave shape. The transformed curve set C' 1804 shows the transformation resulting from a pattern set derived from a square wave shape.

Fig. 19 illustrates a further transformation of the curve set C 1800 (Fig 18A).  
5 The transformed curve set C' 1900 shows a checkerboard effect. The checkerboard effect is achieved during the filling operation and is not part of the transformation as such.

Fig. 20 illustrates a further transformation of the curve set C 1800 (Fig. 18A). The transformed curve set C' 2000 shows a gradient effect. The gradient is applied  
10 during the generation of the pattern set P and is not part of the transformation as such.

#### Preferred Embodiment of Apparatus(s)

The preferred method is preferably practiced using a conventional general-purpose computer, such as the one shown in Fig. 21, wherein the processes of Figs. 5  
15 and 6 may be implemented as software executing on the computer. In particular, the steps of the method are effected by instructions in the software that are carried out by the computer. The software may be divided into two separate parts; one part for carrying out the transformation method; and another part to manage the user interface between the latter and the user. The software may be stored in a computer readable  
20 medium, including the storage devices described below, for example. The software is loaded into the computer from the computer readable medium, and then executed by the computer. A computer readable medium having such software or computer program recorded on it is a computer program product. The use of the computer program product in the computer preferably effects an advantageous apparatus for transforming a  
25 set of closed first curves defined on a surface in accordance with the embodiments of the invention.

The computer system 2100 consists of the computer 2102, a video display 2116, and input devices 2118, 2120. In addition, the computer system 2100 can have any of a number of other output devices including line printers, laser printers, plotters, and

other reproduction devices connected to the computer 2102. The computer system 2100 can be connected to one or more other computers via a communication interface 2108c using an appropriate communication channel 2130 such as a modem communications path, a computer network, or the like. The computer network may  
5 include a local area network (LAN), a wide area network (WAN), an Intranet, and/or the Internet

The computer 2102 itself consists of a central processing unit(s) (simply referred to as a processor hereinafter) 2104, a memory 2106 which may include random access memory (RAM) and read-only memory (ROM), input/output (IO) interfaces 2108a,  
10 2108b & 2108c, a video interface 2110, and one or more storage devices generally represented by a block 2112 in Fig. 21. The storage device(s) 2112 can consist of one or more of the following: a floppy disc, a hard disc drive, a magneto-optical disc drive, CD-ROM, magnetic tape or any other of a number of non-volatile storage devices well known to those skilled in the art. Each of the components 2104 to 2112 is typically  
15 connected to one or more of the other devices via a bus 2114 that in turn can consist of data, address, and control buses.

The video interface 2110 is connected to the video display 2116 and provides video signals from the computer 2102 for display on the video display 2116. User input to operate the computer 2102 can be provided by one or more input devices  
20 2108b. For example, an operator can use the keyboard 2118 and/or a pointing device such as the mouse 2120 to provide input to the computer 2102.

The system 2100 is simply provided for illustrative purposes and other configurations can be employed without departing from the scope and spirit of the invention. Exemplary computers on which the embodiment can be practiced include  
25 IBM-PC/ATs or compatibles, one of the Macintosh (TM) family of PCs, Sun Sparcstation (TM), or the like. The foregoing is merely exemplary of the types of computers with which the embodiments of the invention may be practiced. Typically, the processes of the embodiments, described hereinafter, are resident as software or a program recorded on a hard disk drive (generally depicted as block 2112 in Fig. 21) as



the computer readable medium, and read and controlled using the processor 2104. Intermediate storage of the program and pixel data and any data fetched from the network may be accomplished using the semiconductor memory 2106, possibly in concert with the hard disk drive 2112.

5 In some instances, the program may be supplied to the user encoded on a CD-ROM or a floppy disk (both generally depicted by block 2112), or alternatively could be read by the user from the network via a modem device connected to the computer, for example. Still further, the software can also be loaded into the computer system 2100 from other computer readable medium including magnetic tape, a ROM or  
10 integrated circuit, a magneto-optical disk, a radio or infra-red transmission channel between the computer and another device, a computer readable card such as a PCMCIA card, and the Internet and Intranets including email transmissions and information recorded on websites and the like. The foregoing is merely exemplary of relevant computer readable mediums. Other computer readable mediums may be practiced  
15 without departing from the scope and spirit of the invention.

#### Applications

The preferred embodiment has many areas of application and a number of examples follow but are not seen as exhaustive. One application is the use of the  
20 preferred embodiment in the generation of different typefaces or fonts. Another application of the preferred embodiment is in the generation of patterns on objects in digital videos for special effects.

The foregoing only describes a small number of embodiments of the present invention, however, modifications and/or changes can be made thereto by a person  
25 skilled in the art without departing from the scope and spirit of the invention.

The following numbered paragraphs set forth aspects of the invention, including

1. A method for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the method including the steps  
5 of;

(i) providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

(ii) determining a set of intersection points of the set of first curves with the  
10 set of second curves;

(iii) determining a set of crossover points within the set of intersection points;  
and

(iv) selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to  
15 form closed loops; wherein the closed loops form said transformed set of closed curves.

2. A method as set forth in paragraph 1, wherein said step (iv) includes the substeps of:

(iv)(1) ordering all the crossover points in accordance with a predetermined  
20 order;

(iv)(2) marking one of said crossover points that is highest in the order and that has not been previously marked;

(iv)(3) determining, if a last marked crossover point is a first point in a said closed loop, and if so:

25 (iv)(3)(i) selecting one of said curve intervals starting at said first point and terminating at an unmarked crossover point; and

(iv)(3)(ii) marking the terminating crossover point of said one curve interval;

or if not:

(iv)(3)(iii)selecting a further said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point; and

(iv)(3)(iv)marking the current terminating crossover point of said further curve interval;

5 (iv)(4) repetitively performing the substep (iv)(3) until said closed loop is formed; and

(iv)(5) repetitively performing the substeps (iv)(2) to (iv)(4) until all possible closed loops have been formed.

10 3. A method as set forth in paragraph 2, wherein said substep (iv)(3)(i) includes selecting a further said curve intervals from the set of first curves, which said one curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

15 4. A method as set forth in paragraph 2 or 3, wherein said substep (iv)(3)(iii) includes selecting a said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

20

5. A method as set forth in paragraph 2,3 or 4, wherein said substep of ordering said crossover points includes ordering the crossover points according to their position along the set of first curves in a fourth direction.

25 6. A method as set forth in paragraph 5, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

7. A method as set forth in paragraph 5, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.
- 5 8. A method as set forth in any one of the preceding paragraphs, wherein said surface is a 2-dimensional surface.
9. A method as set forth in any one of paragraphs 1 to 7, wherein said surface is a 3-dimensional surface.
- 10 10. A method as set forth in any one of the preceding paragraphs, wherein said step of selecting curve intervals includes the substep of filling the closed loops with a predetermined color.
- 15 11. A method as set forth in any one of the preceding paragraphs, wherein said step of providing a pattern, includes the substep of:  
generating said pattern.
12. A method as set forth in any one of the preceding paragraphs 1 to 10, wherein  
20 said step of providing a pattern, includes the substep of:  
accessing said pattern from storage.
13. A method as set forth in any one of the preceding paragraphs, wherein said step of providing a pattern, includes the substep of:  
25 selecting one of many said patterns in response to user input.
14. A method as set forth in paragraph 11, wherein said generating step includes inputting parameters.

15. A method as set forth in paragraph 14, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or amplitude of the patterns.

5 16. A method as set forth in 15, wherein the amplitude of the pattern varies throughout the pattern.

17. A method as set forth in any one of the preceding claims, wherein the set of first curves constitutes a character glyph of a font.

10

18. An apparatus for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second  
15 curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

20 a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

25 19. An apparatus as set forth in paragraph 18, wherein said first selecting means includes:

ordering means for ordering all the crossover points in accordance with a predetermined order;

a first marking means for marking one of said crossover points that is highest in the order and that has not been previously marked;

a second selecting means for selecting one of said curve intervals starting at a first point and terminating at an unmarked crossover point;

5 a second marking means for marking the terminating crossover point of said one curve interval;

a third selecting means for selecting a said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point;

10 a third marking means for marking the current terminating crossover point of said one curve interval;

a third determining means for determining, if a last marked crossover point is the first point in a said closed loop, and if so performing the operations of the second selecting means and the second marking means, or if not, performing the operations of the third selecting means and third marking means;

15 means for repetitively performing the operations of the third determining means until said closed loop is formed; and

means for repetitively performing the operations of first marking means and third determining means until all possible closed loops have been formed.

20 20. An apparatus as set forth in paragraph 19, wherein said second selecting means selects one of said curve intervals from the set of first curves, which said one curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

25 21. An apparatus as set forth in paragraph 19 or 20, wherein said third selecting means selects a further said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

22. An apparatus as set forth in paragraph 19, 20 or 21, wherein said ordering means orders the crossover points according to their position along the set of first curves in a fourth direction.

5

23. An apparatus as set forth in paragraph 22, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

10 24. An apparatus as set forth in paragraph 22, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.

15 25. An apparatus as set forth in any one of the preceding paragraphs 18 to 24, wherein said surface is a 2-dimensional surface.

26. An apparatus as set forth in any one of the preceding paragraphs 18 to 24, wherein said surface is a 3-dimensional surface.

20 27. An apparatus as set forth in any one of the preceding paragraphs 18 to 26, wherein said first selecting means includes means for filling the closed loops with a predetermined color.

25 28. An apparatus as set forth in any one of the preceding paragraphs 18 to 27, wherein said providing means includes means for generating said pattern.

29. An apparatus as set forth in any one of the preceding paragraphs 18 to 27, wherein said providing means includes means for accessing said pattern from storage.

30. An apparatus as set forth in any one of the preceding paragraphs 18 to 29, wherein said providing means includes means for selecting one of many said patterns in response to user input.

5 31. An apparatus as set forth in paragraph 28, wherein said generating means includes means for inputting parameters.

32. An apparatus as set forth in paragraph 31, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or  
10 amplitude of the patterns.

33. An apparatus as set forth in 32, wherein the amplitude of the pattern varies throughout the pattern.

15 34. An apparatus as set forth in any one of the preceding claims 18 to 33, wherein the set of first curves constitutes a character glyph of a font.

35. A computer program product including a computer readable medium having recorded thereon a computer program for transforming a set of closed first curves  
20 defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

25 a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and



a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

5

36. A computer program product as set forth in paragraph 35, wherein said first selecting means includes:

ordering means for ordering all the crossover points in accordance with a predetermined order;

10 a first marking means for marking a said crossover point that is highest in the order and that has not been previously marked;

a second selecting means for selecting a said curve interval starting at a first point and terminating at an unmarked crossover point;

a second marking means for marking the terminating crossover point;

15 a third selecting means for selecting a said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point;

a third marking means for marking the current terminating crossover point;

a third determining means for determining, if the last marked crossover point is the first point in a said closed loop, and if so performing the operations of the second  
20 selecting means and the second marking means, or if not, performing the operations of the third selecting means and third marking means;

means for repetitively performing the operations of the third determining means until said closed loop is formed; and

25 means for repetitively performing the operations of first marking means and third determining means until all possible closed loops have been formed.

37. A computer program product as set forth in paragraph 36, wherein said second selecting means selects a said curve interval from the set of first curves, which said

curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

38. A computer program product as set forth in paragraph 36 or 37, wherein said  
5 third selecting means selects a said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

10

39. A computer program product as set forth in paragraph 36, 37 or 38, wherein said ordering means orders the crossover points according to their position along the set of first curves in a fourth direction.

15 40. A computer program product as set forth in paragraph 39, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

20 41. A computer program product as set forth in paragraph 39, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.

25 42. A computer program product as set forth in any one of the preceding paragraphs 35 to 41, wherein said surface is a 2-dimensional surface.

43. A computer program product as set forth in any one of the preceding paragraphs 35 to 41, wherein said surface is a 3-dimensional surface.

44. A computer program product as set forth in any one of the preceding paragraphs 35 to 43, wherein said first selecting means includes means for filling the closed loops with a predetermined color.

5

45. A computer program product as set forth in any one of the preceding paragraphs 35 to 44, wherein said providing means includes means for generating said pattern.

46. A computer program product as set forth in any one of the preceding paragraphs 35 to 44, wherein said providing means includes means for retrieving said pattern from storage.

47. A computer program product as set forth in any one of the preceding paragraphs 35 to 46, wherein said providing means includes means for selecting one of many said patterns in response to user input.

15

48. A computer program product as set forth in paragraph 45, wherein said generating means includes means for inputting parameters.

49. A computer program product as set forth in paragraph 48, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or amplitude of the patterns.

20

50. A computer program product as set forth in 49, wherein the amplitude of the pattern varies throughout the pattern.

25

51. A computer program product as set forth in any one of the preceding claims 35 to 50, wherein the set of first curves constitutes a character glyph of a font.

**Dated 28 August, 1998**  
**Canon Kabushiki Kaisha**

**Patent Attorneys for the Applicant/Nominated Person**  
**SPRUSON & FERGUSON**

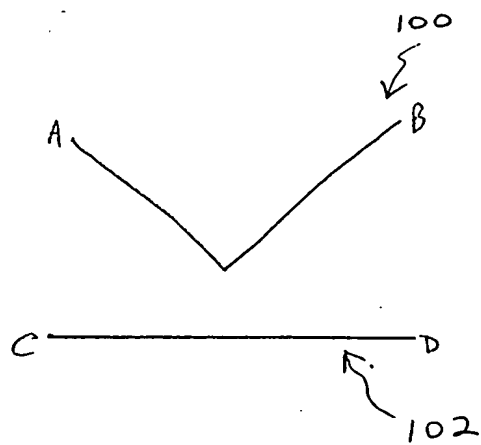


FIG. 1A

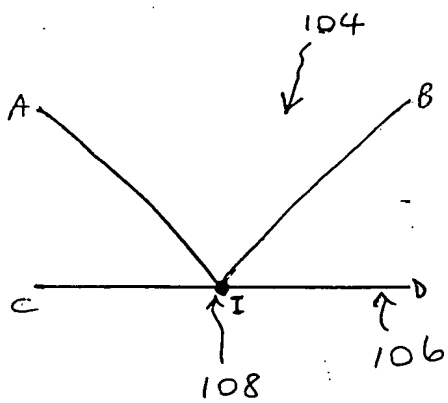


FIG. 1B

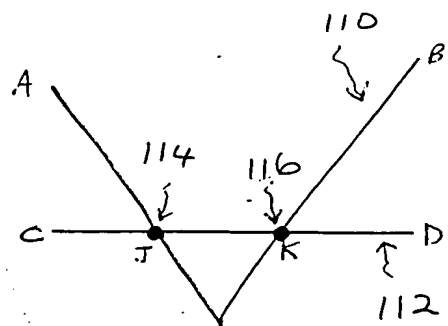


FIG. 1C

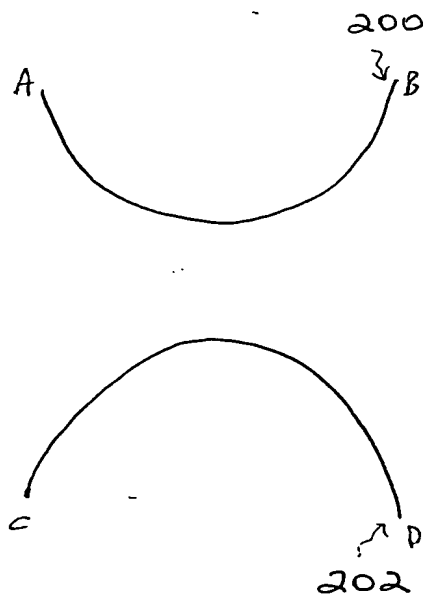


FIG. 2A

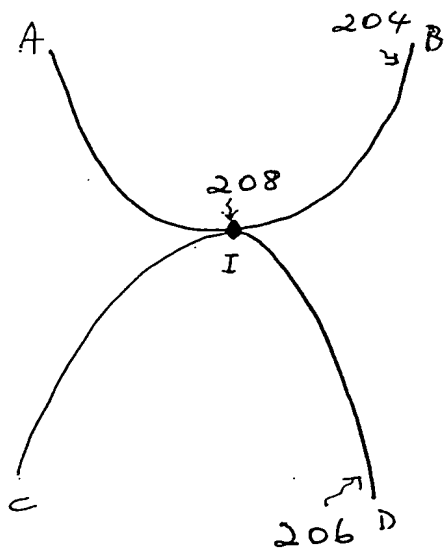


FIG. 2B

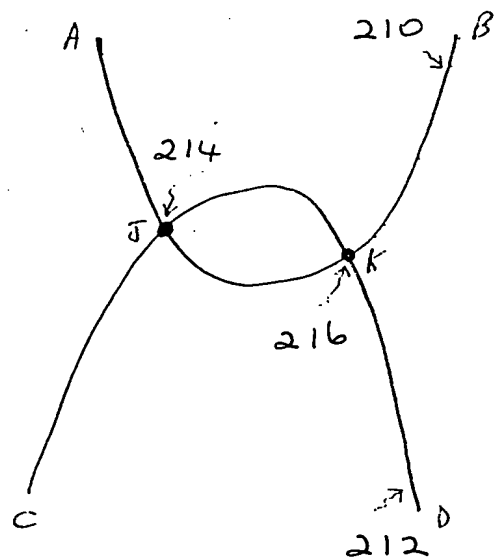


FIG. 2C

FIG. 3A

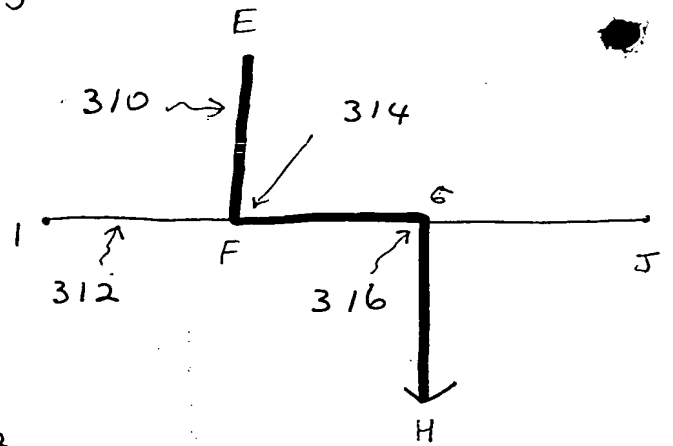
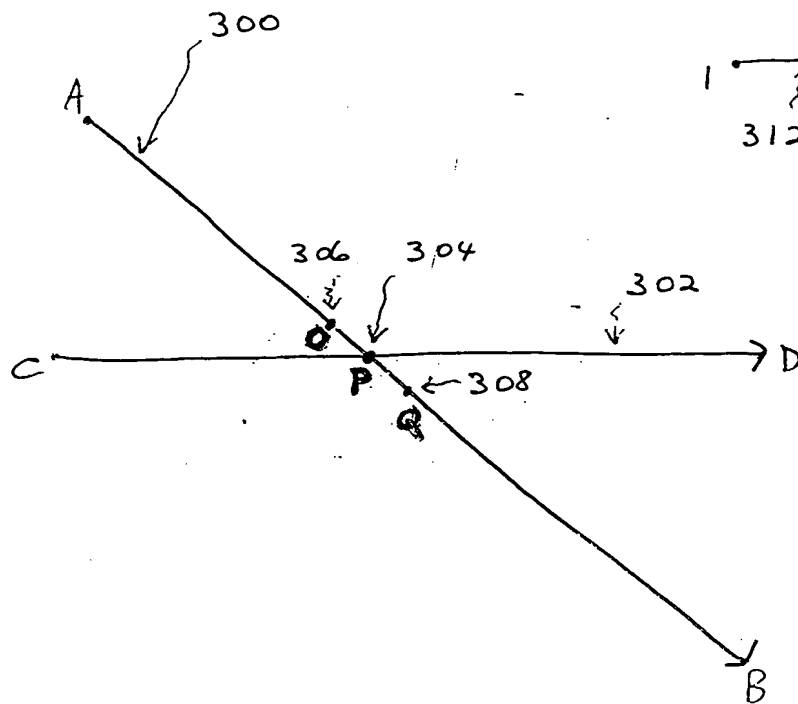
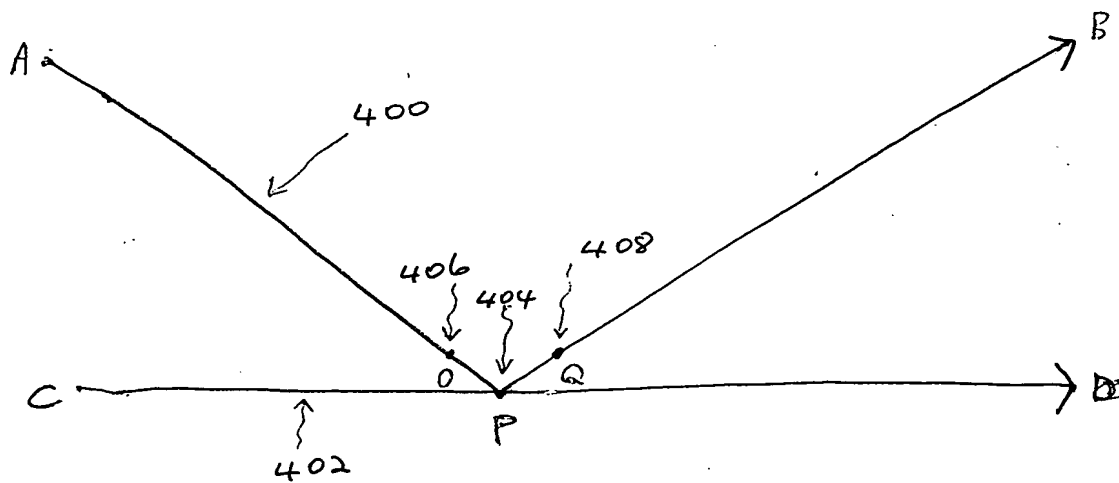


FIG. 3B

Fig. 4A



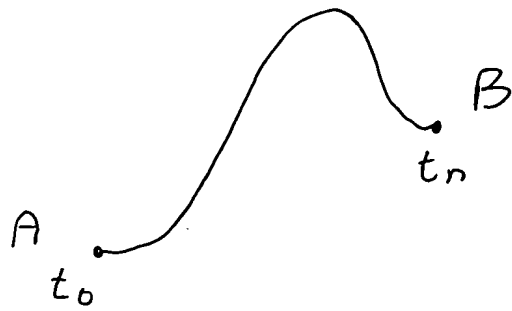


Fig. 4B

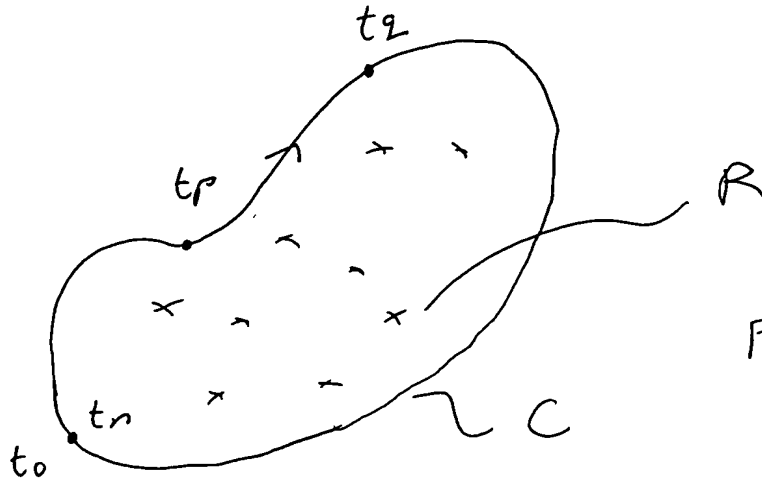


Fig. 4C

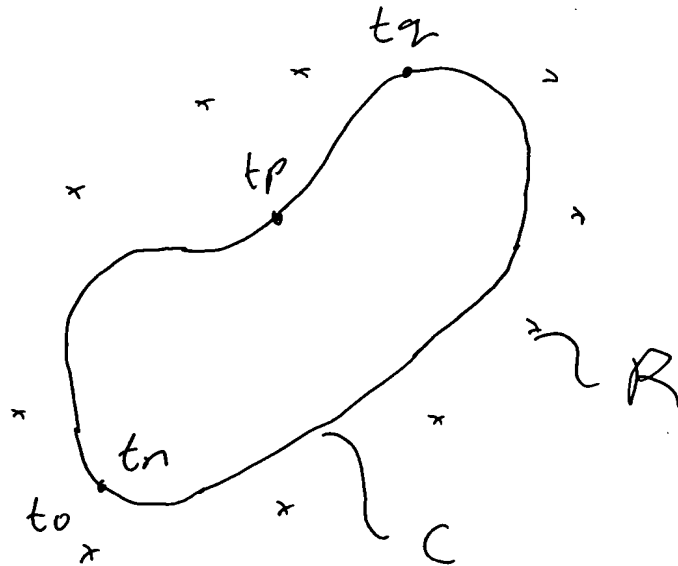


Fig 4D

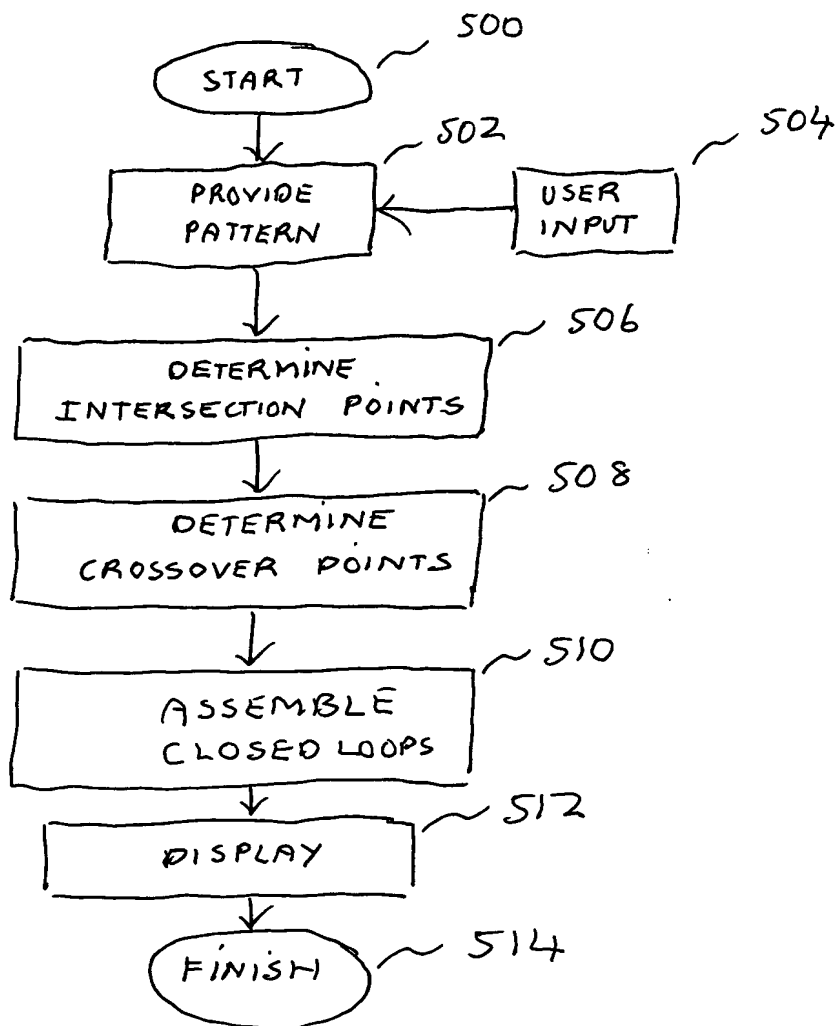


FIG. 5



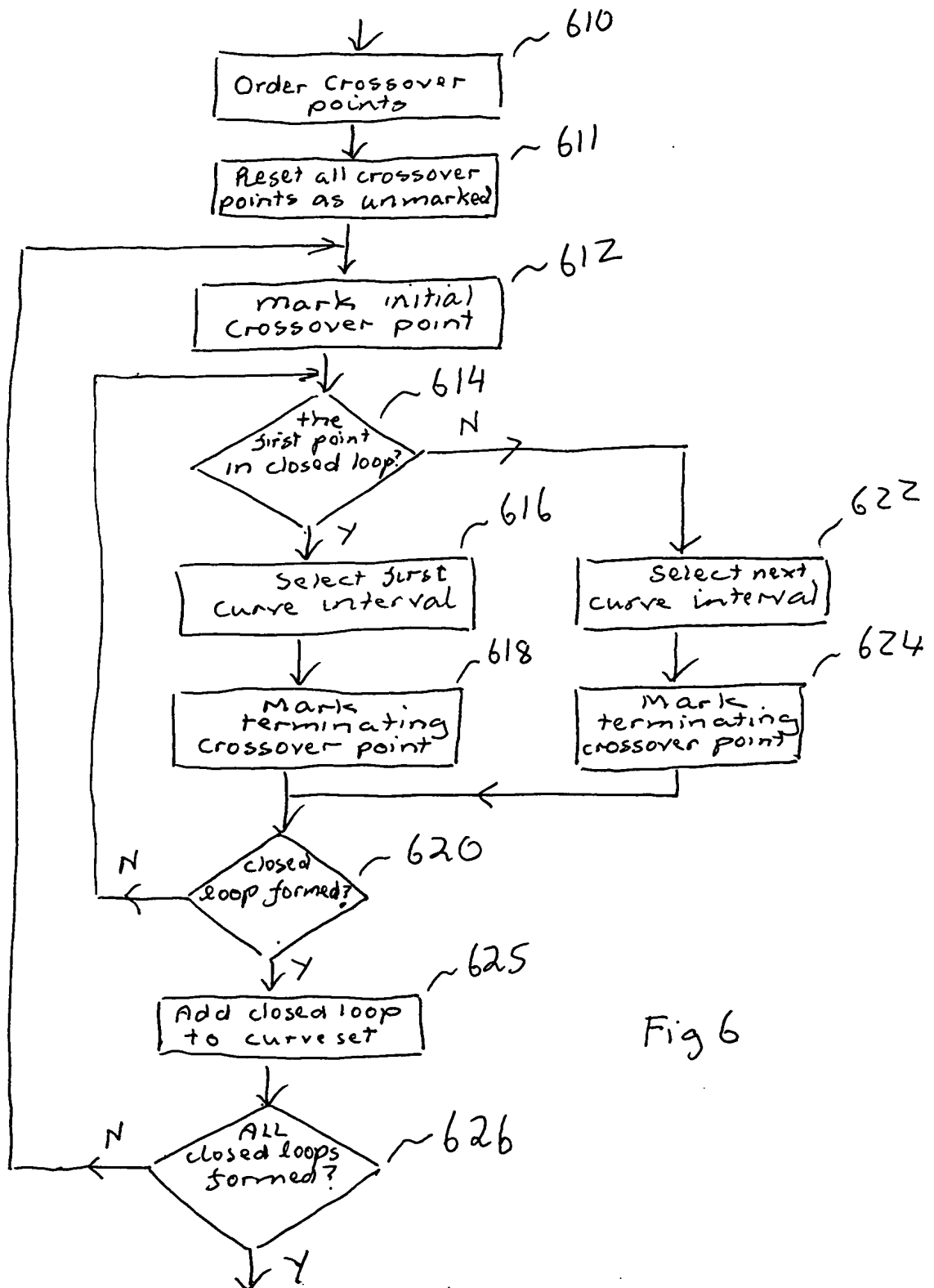


Fig 6

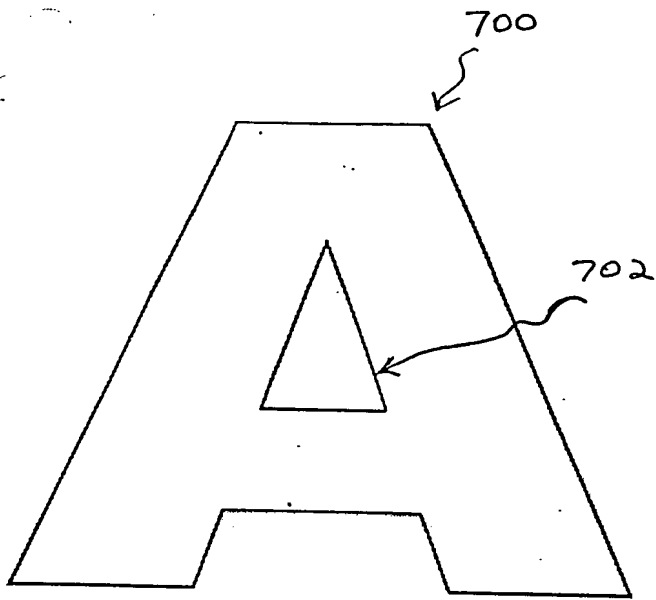


Fig. 7A

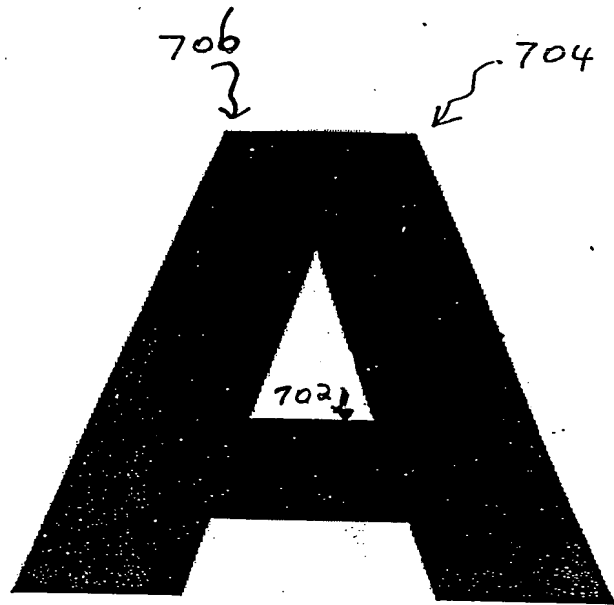
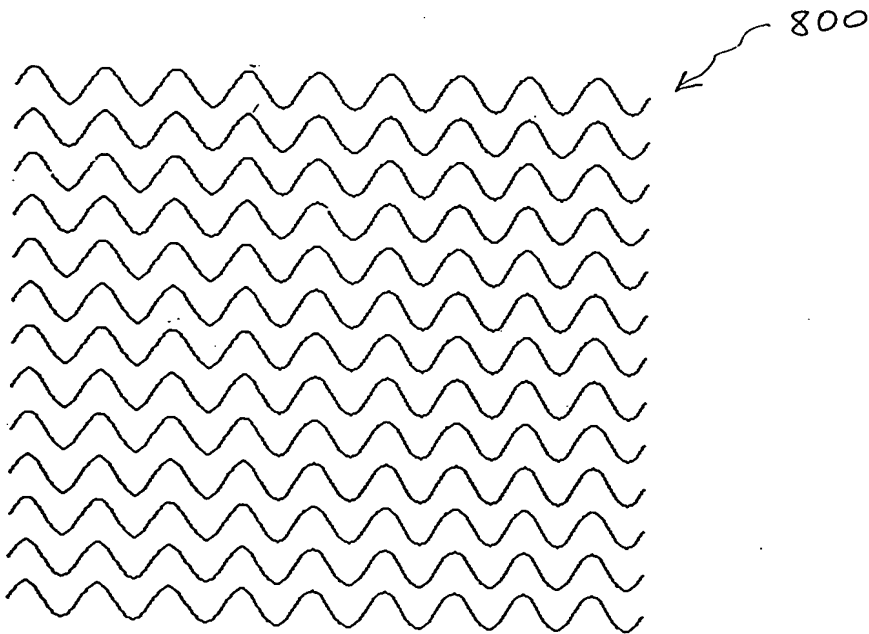


Fig. 7B

Fig. 8



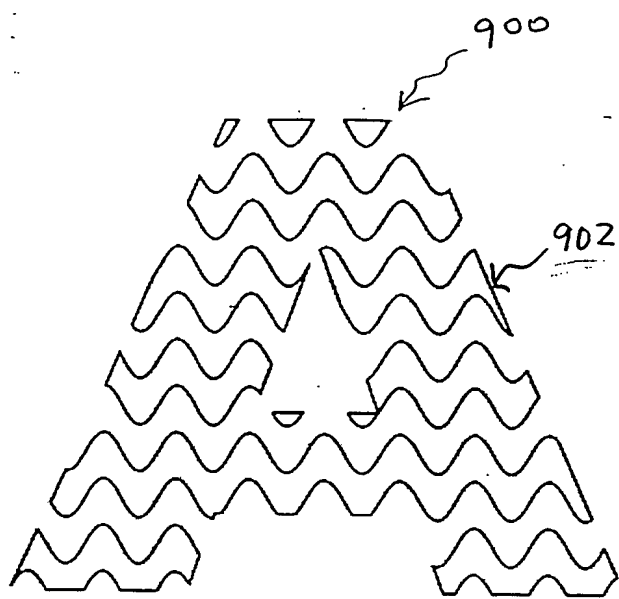


Fig. 9A

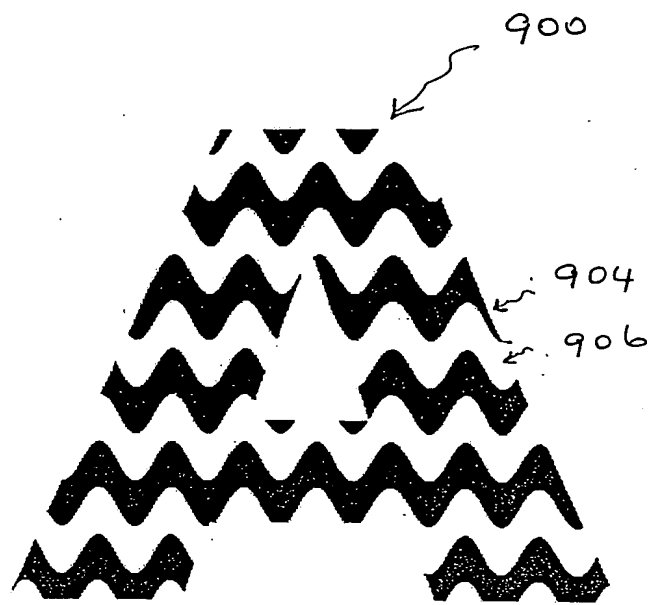


Fig. 9B

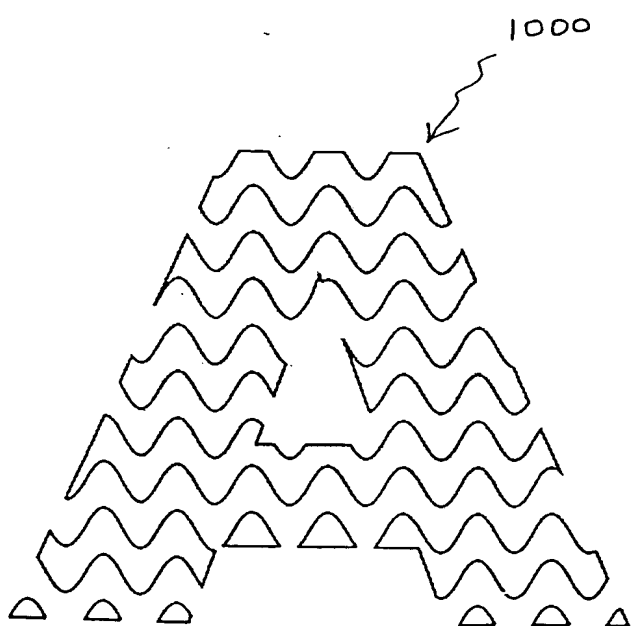


Fig. 10A

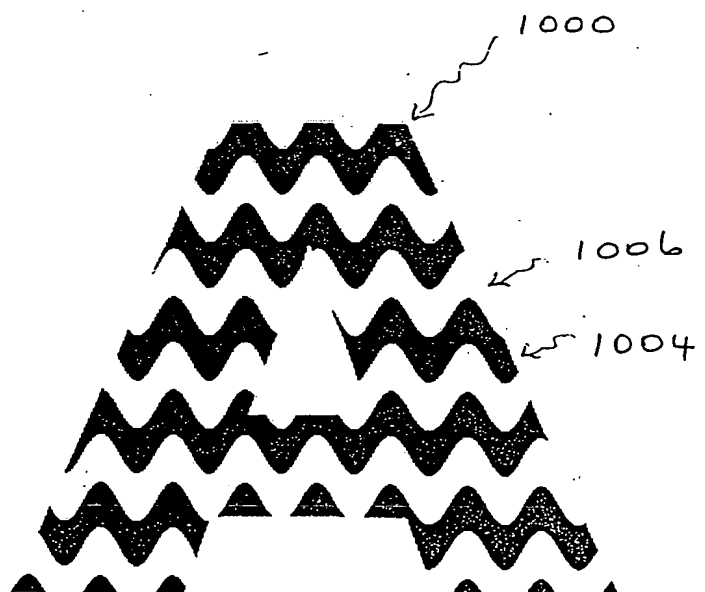


Fig. 10B

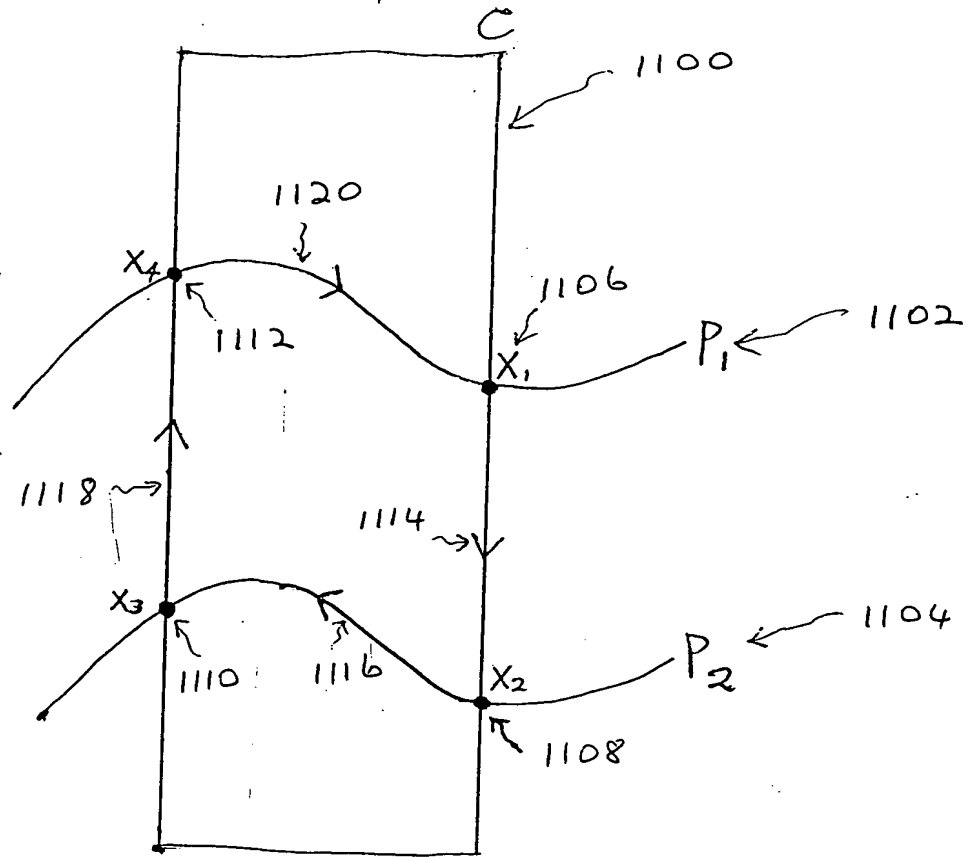


Fig. 11A

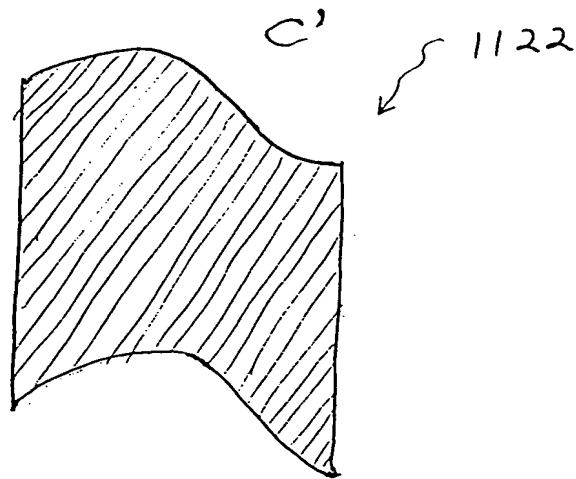
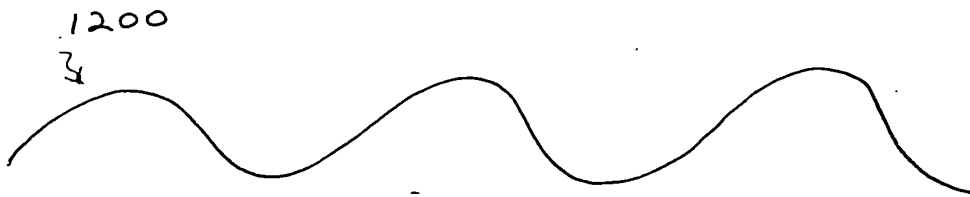


Fig. 11B

Fig. 12



1202 ~>

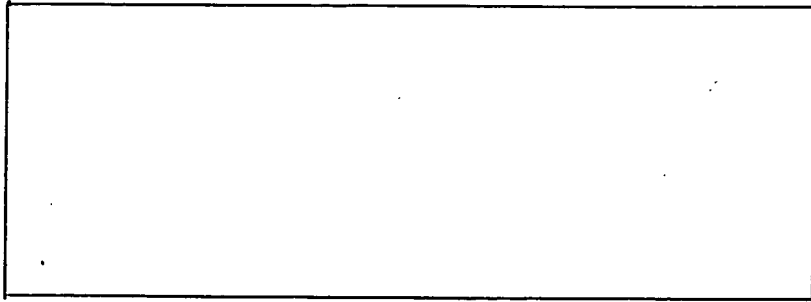


Fig. 13

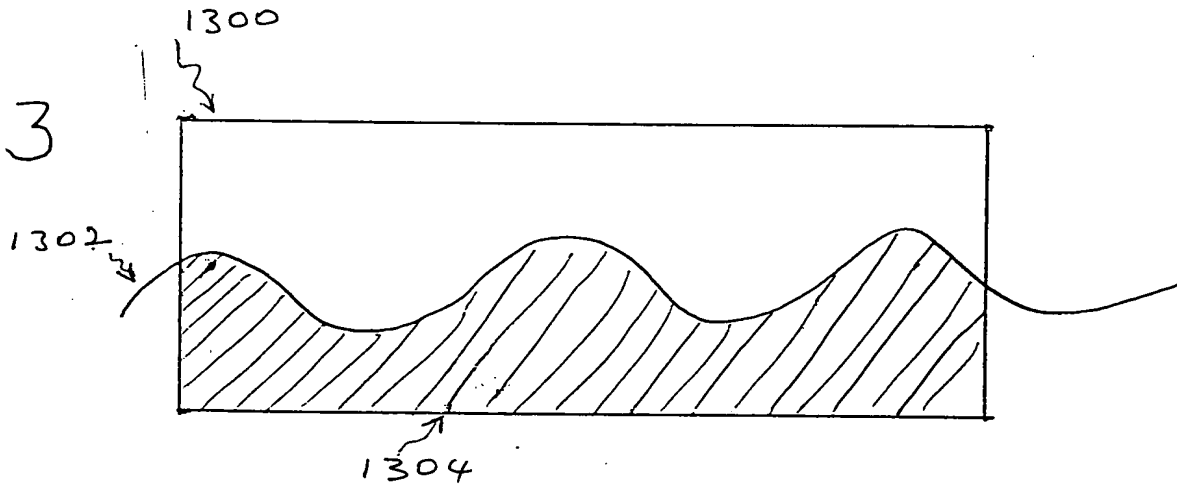
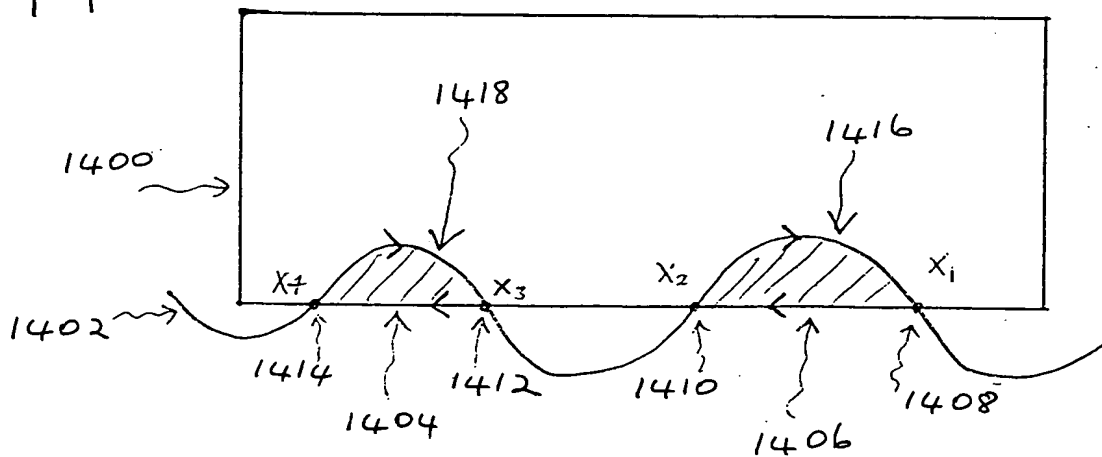


Fig. 14



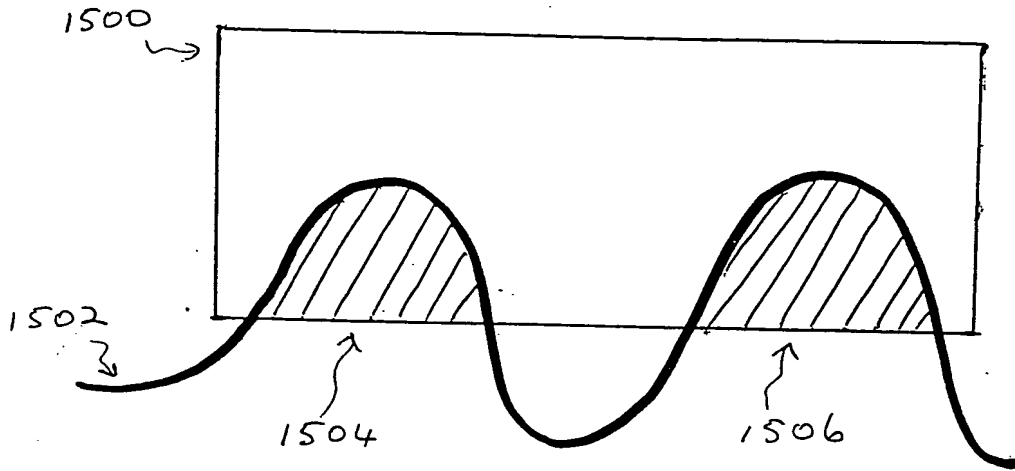


Fig. 15A

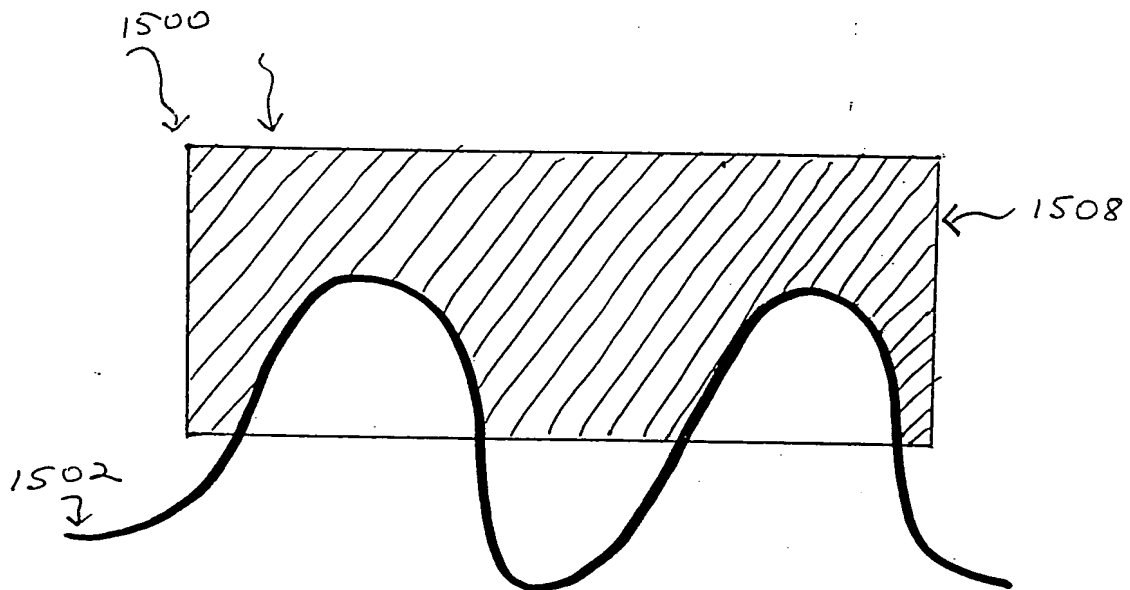


Fig. 15B

Fig. 16

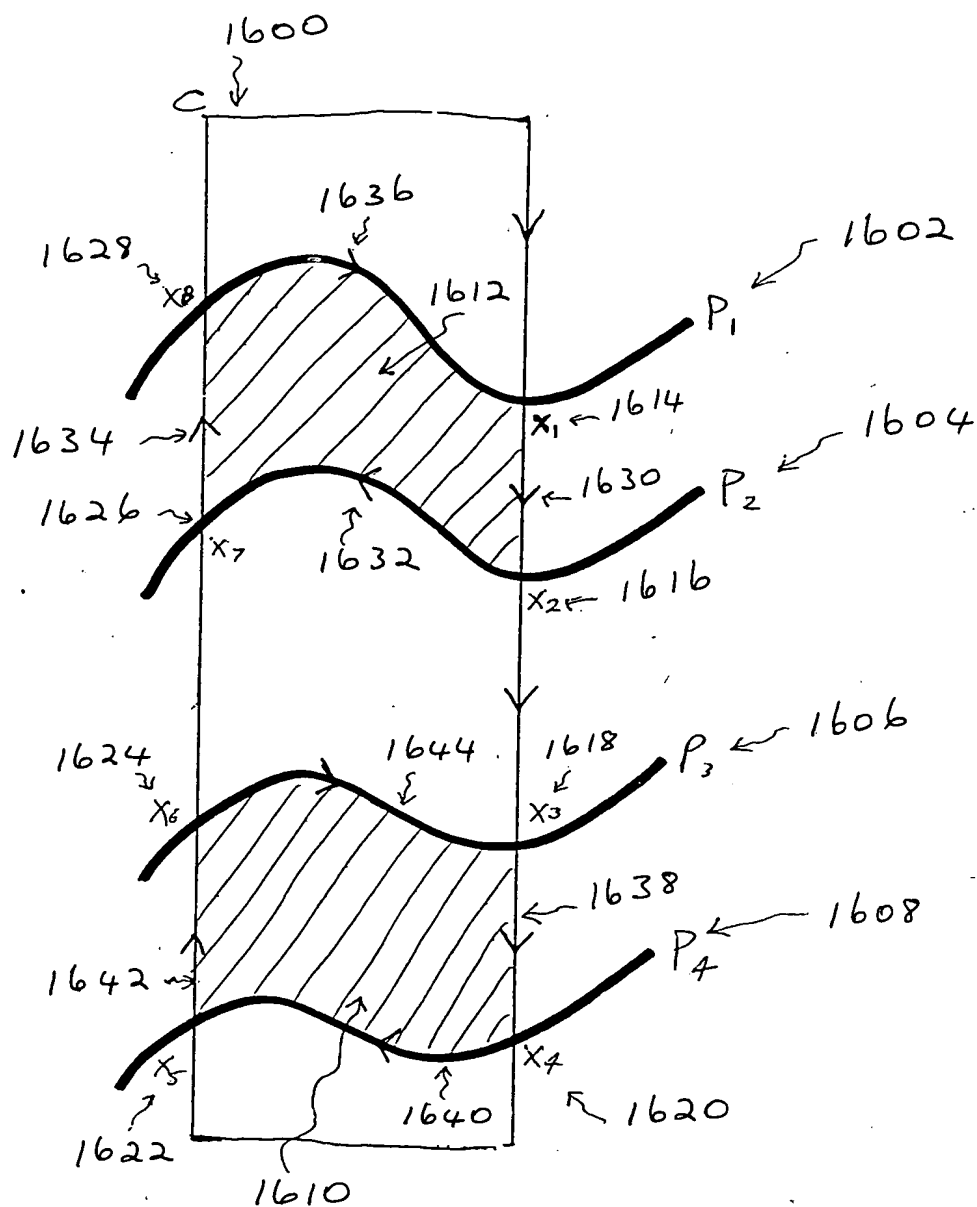
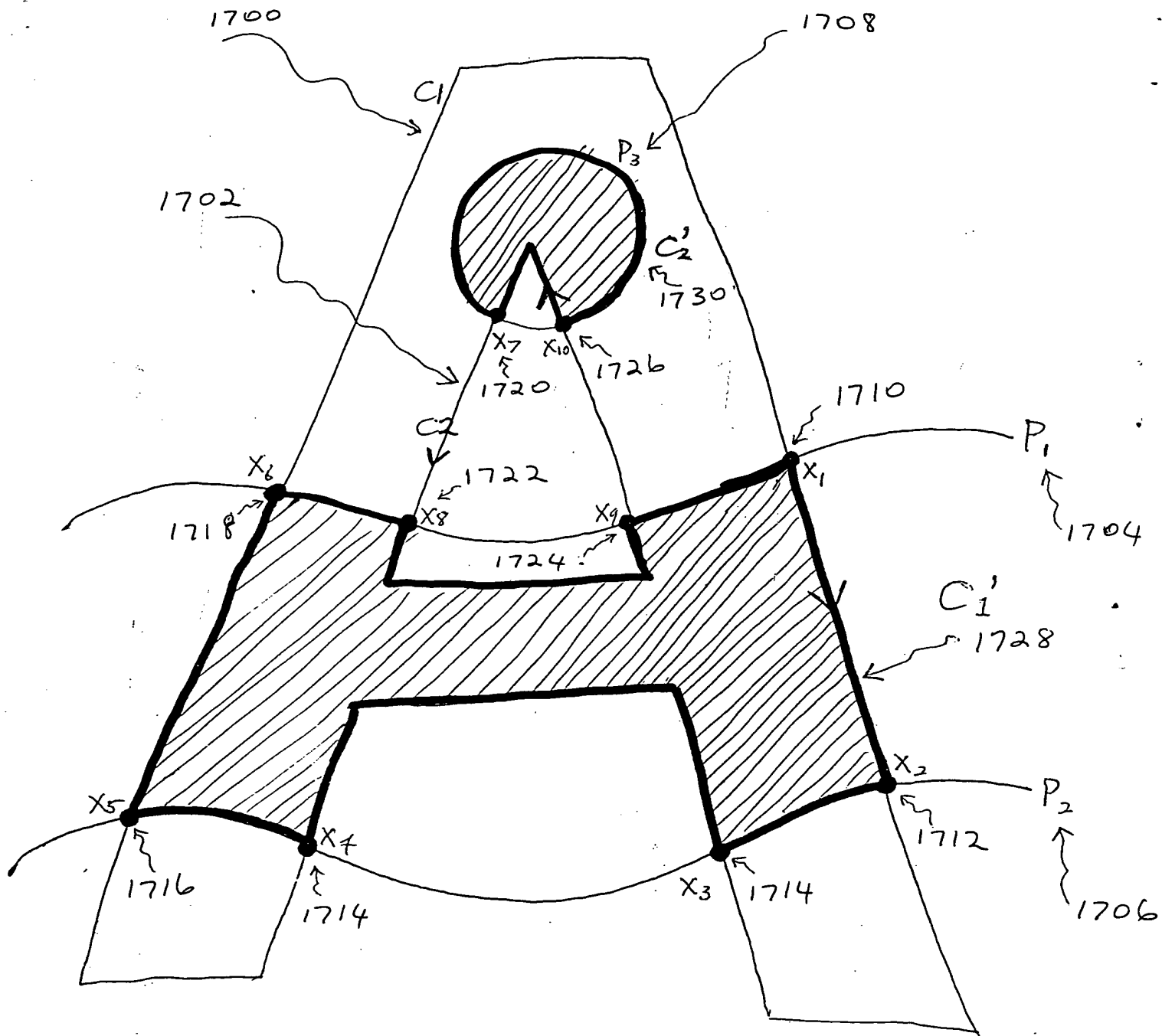


Fig. 17





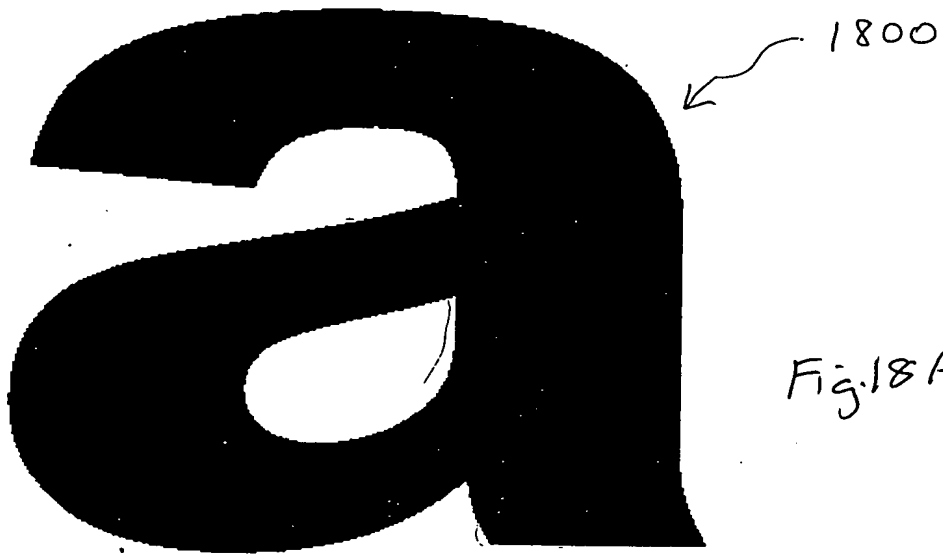


Fig. 18A

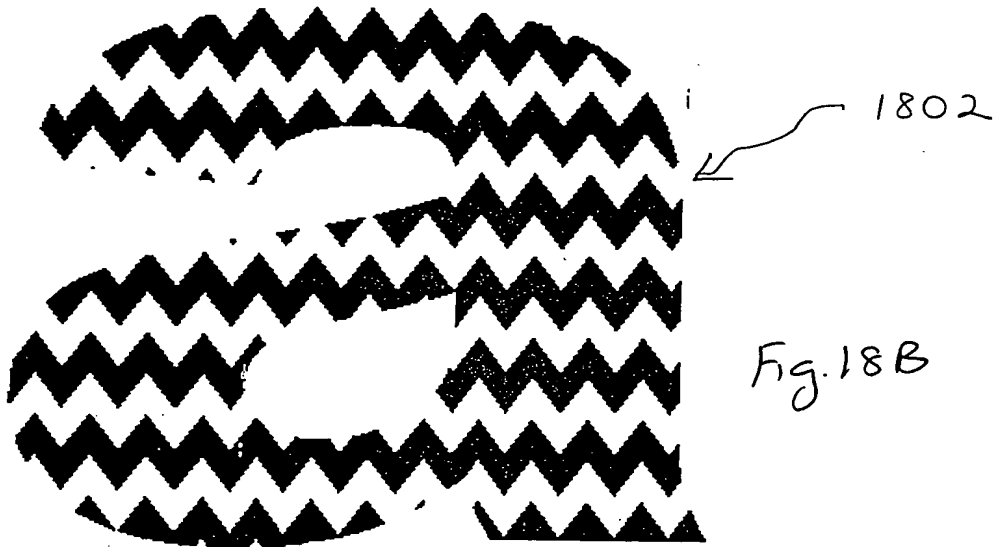


Fig. 18B

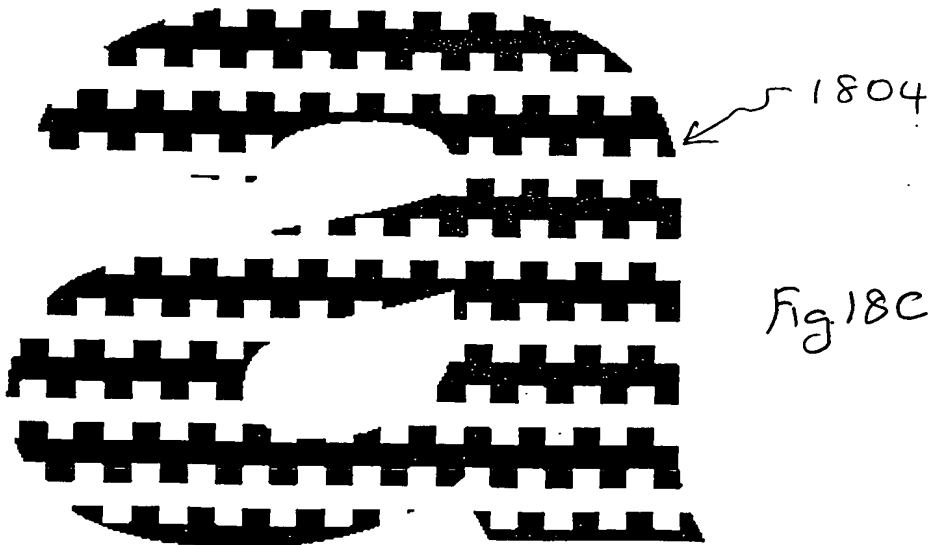


Fig. 18C

Fig. 19

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1900  
~>

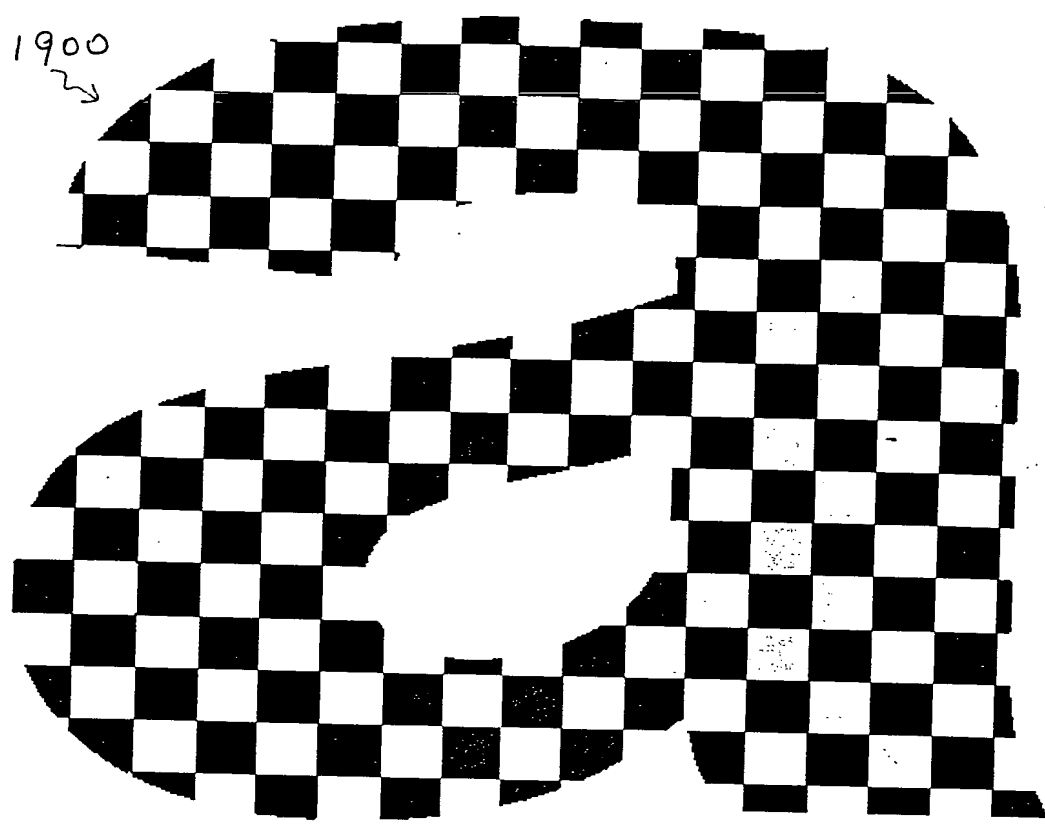
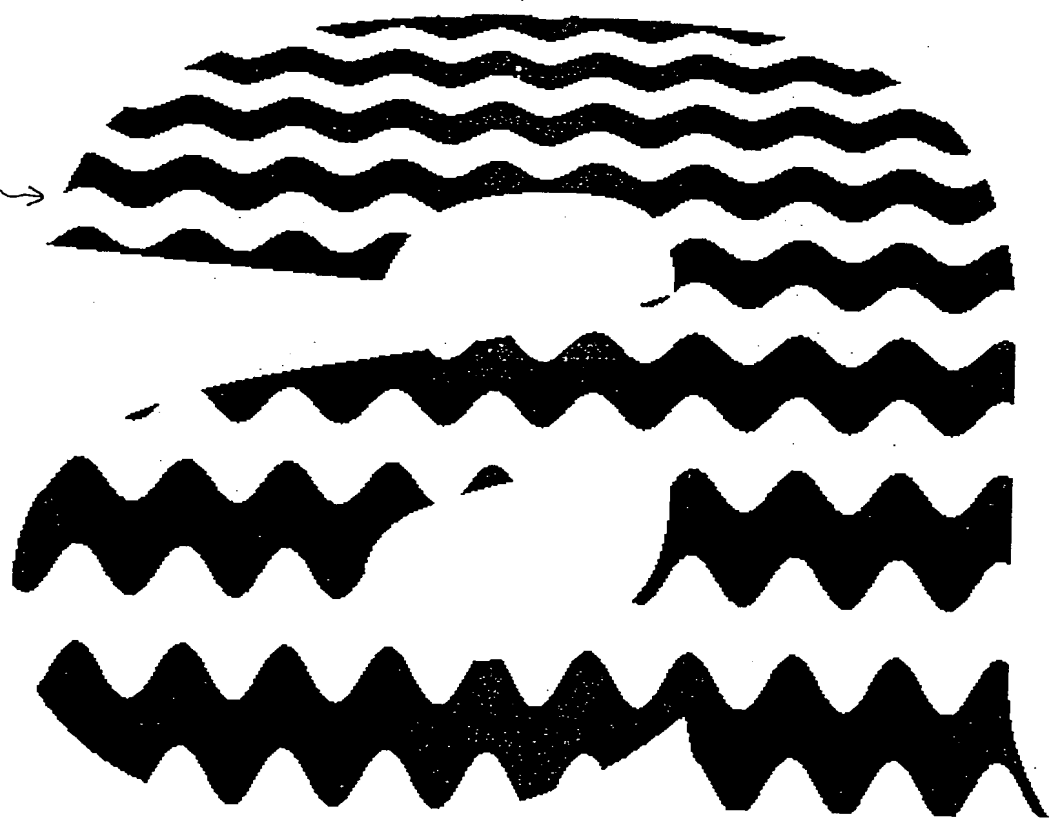
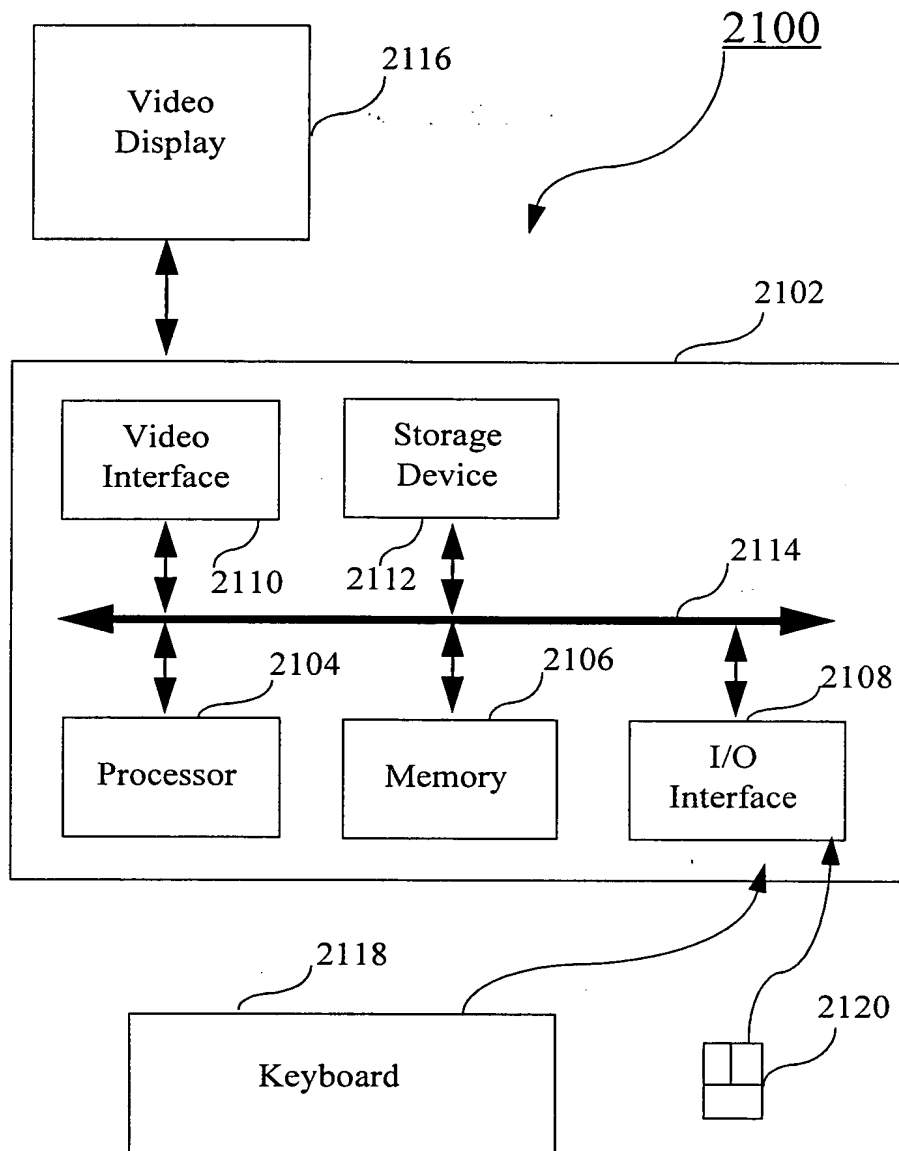


Fig. 20

2000 ~>





**Fig. 21**

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